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(56) Documents Cited

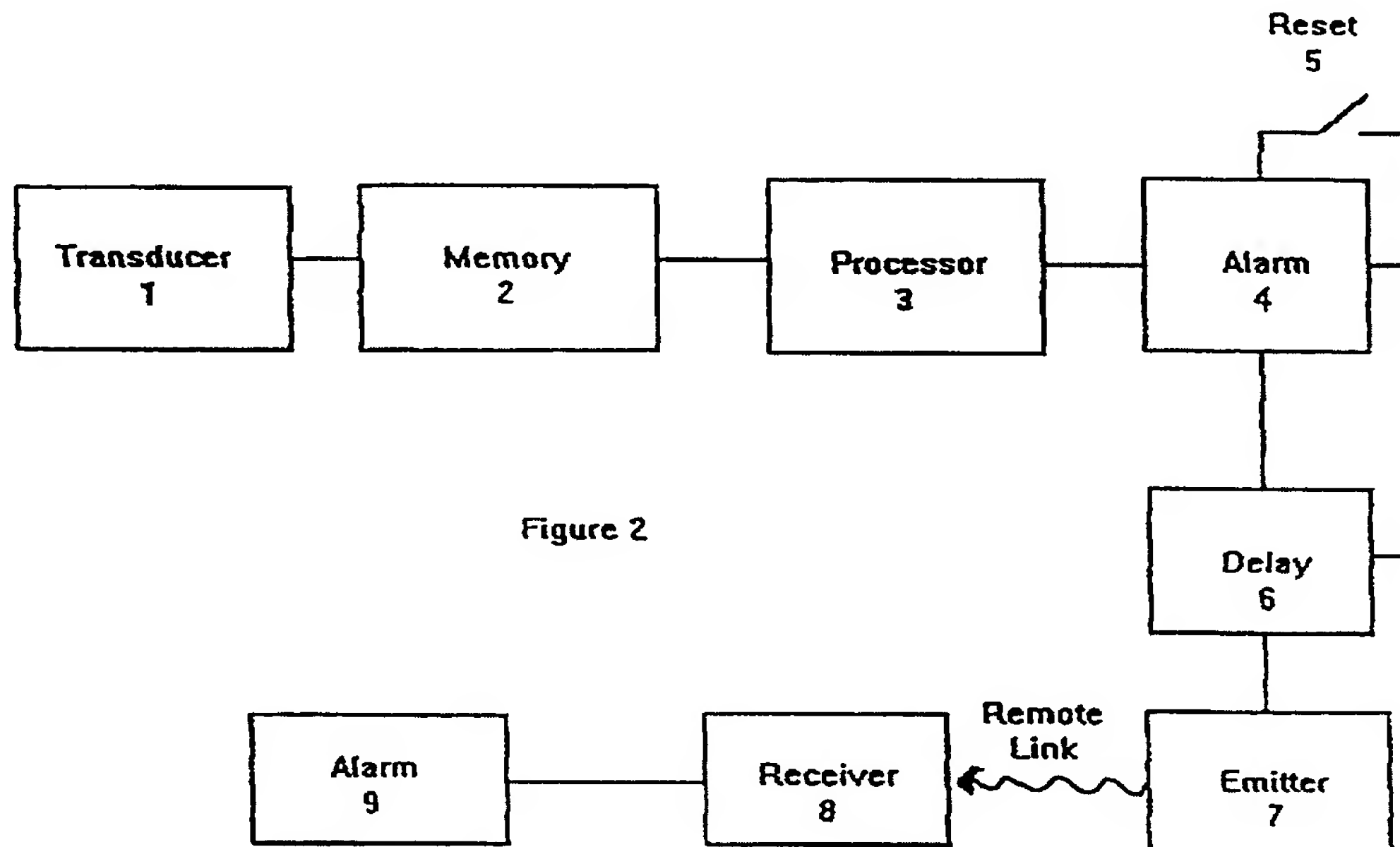
GB 2150725 A GB 1416425 A US 4728939 A
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(58) Field of Search

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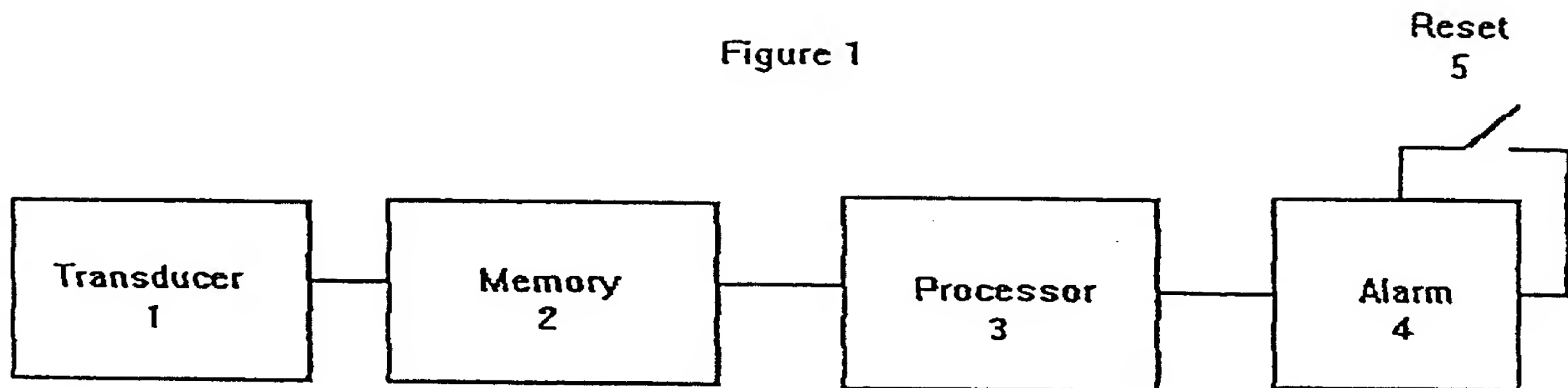
(54) **Sleep detection and alarm system**

(57) A system for waking an individual upon onset of sleep comprises a wearable device and an alarm, the wearable device comprising a sleep detector 1,2,3 for determining the sleep/wake state of an individual when wearing the device, a signal generator 3 that provides an activating signal for the alarm 4 upon detection of a sleep state by the detector 1,2,3, and manually operable alarm reset means 5. The wearable device preferably comprises the alarm 4. The system may comprise a second alarm 9 which is activated if the first alarm 4 is not reset within a pre-determined time, indicative of the wearer not having been awakened by the first alarm 4. The sleep detector may monitor wrist motion, blood pressure or pulse rate.



$\frac{1}{2}$

Figure 1



2
1/2

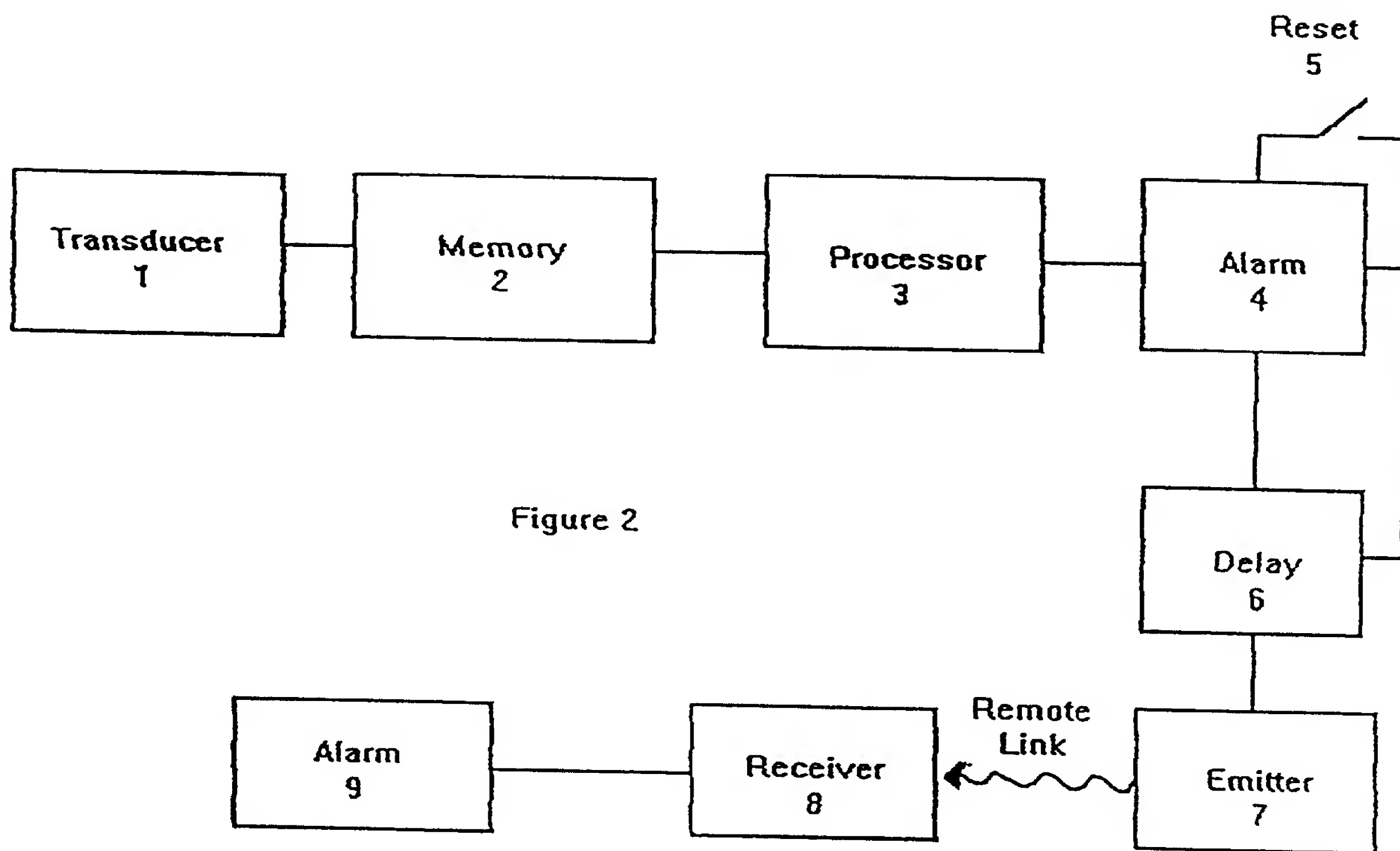


Figure 2

SLEEP DETECTION AND ALARM SYSTEM

The present invention relates to a system which on detection of the onset of sleep in an individual activates an alarm with the aim of waking the individual. In particular, the invention relates to such a system that comprises a portable device, preferably to be worn on the wrist.

Various ways for the determination of the waking or sleeping state of individuals are available.

Typical ways of determining the onset of sleep include measurements of pulse, respiration and muscle movement and also polysomnographic recording. As the sleeping state is approached, these physiological signs show fundamental changes which may be measured.

It has been found (Mullany DJ et al, Sleep, 1980, 3:82-91) that one particularly successful method of unobtrusively identifying the sleeping state is based on wrist activity. Cole et al (American Sleep Disorders Association and Sleep Research Society, 1992, 15(5), 461-469) published an automatic sleep/wake identification method based on this work. Wrist activity is measured and stored as a function of time using a commercially available Mini-Motionlogger Actigraph (motional transducer). This is available from Ambulatory Monitoring Inc, 731 Saw Mill Road, Ardsley, New York, USA. Mini-Motionlogger Actigraph is a trade mark. This record of wrist activity is then extracted from the actigraph at a later time by an additional device and analysed using a

computer. Optionally, an algorithm essentially averages the measured wrist activity over a set period of time. Periods of low activity are equated with the sleeping state and periods of high activity with the waking state.

5 The duration of wrist movements during sleep and sleepiness is substantially greater than during awake, alert periods.

In order to test the accuracy of this method, Cole et al simultaneously made polysomnographic measurements on

10 the same subjects. There is a better than 80% agreement of the assignment of sleeping and waking states between the two methods in most patients, the accuracy being insensitive to small changes in the averaging algorithm.

Some vehicles such as aircraft have sleep detectors.

15 For example, in one system a camera measures movement, usually eye movement, to detect the sleeping state. The system may then attempt to wake the subject with an alarm of some form, typically by blowing air on the subject or by playing a recorded message. Various disadvantages are

20 associated with such devices, not least the fact that the subject has a very restricted range of movement if the system is to be effective.

The present inventor has realised the advantages of providing a device comprising a portable, preferably

25 wearable, sleep detector and alarm. A wearer of the device may have complete freedom of movement and should be woken on onset of sleep. The sleep detector may be appropriately calibrated so as to determine onset of

sleep, i.e. that a subject is in a sleep state as opposed to awake, at a certain level of sleepiness or drowsiness rather than when the subject is fully asleep.

Thus, according to the present invention there is
5 provided a system for waking an individual upon onset of sleep, the system comprising a sleep detector and a manually resettable alarm. The sleep detector is a component of a portable, preferably wearable device that generally also comprises manually operable reset means for
10 the alarm. A signal generator provides an activating signal for the alarm upon detection of a sleep state by the detector.

The alarm is preferably included in the portable or wearable device but may be separate, provided a suitable
15 activating signal is generated by the signal generator. For instance, the alarm may be remote from the device, e.g. in a building or vehicle, in which case it may be activated by an optical signal such as infra-red or by a radio signal.

20 The device is preferably wearable on the wrist, though embodiments may be provided for wearing on any part of the body, for example on the leg or round the neck. For attachment to the body, the device may comprise a strap or belt and buckle. One advantage of using a
25 wearable device is the lack of restriction on movement of the wearer, particularly if the alarm is included in the wearable device. A further, important advantage may arise from the alarm reset means being included in the wearable

device, that is the need for a positive physical movement in order to reset the alarm. For instance, if the device is worn on a wrist of one arm of an individual, operation of the alarm reset will require use of the other arm.

5 This action is likely to require conscious effort, in turn requiring a certain level of awareness or awakening.

A system according to the present invention has a range of important applications. For example, it may be used by truck drivers, motorists or coach drivers, airline
10 pilots, and so on. Other applications may include workers manning dangerous machinery, possibly at a range of sites or positions where conventional sleep detection apparatus would not be able to keep track of the operatives.

The system may also be used by medical staff or
15 security guards who may cover large areas during their shifts. Security guards often work in isolation where the system would be particularly useful.

The sleep detector may comprise a motion sensor.

The motion sensor may comprise a motional transducer
20 such as an actigraph system for measuring the duration of movements of the wearer. The motion sensor may comprise a device for measuring the frequency of movements of the wearer. The motion sensor may comprise an accelerometer which converts measured acceleration of the sensor into a
25 signal.

The portable or wearable device may comprise a signal processor that may comprise a memory for recording the signal generated by the motion sensor and a computer

or computing element for interpreting the measured data in order to determine the sleep/wake state of the wearer.

An averaging algorithm such as the Webster algorithm may be used in the determination of the waking or sleeping state, the algorithm (Webster et al, *Sleep* (1982) 5: 389-399; see also Cole, et al) using measured velocity as a function of time to determine the sleeping or waking state.

A suitable algorithm may use measured acceleration as a function of time to determine the sleeping or waking state.

A digital or an analogue circuit may be employed.

The sleep detector may comprise a device for measuring blood pressure or pulse rate.

Use of a non-invasive mode of determination of the sleep/wake state, which is generally the case in the present invention, allows for various advantages including minimal discomfort to the subject, simplicity of operation and an absence of side-effects. It allows for prolonged use of the system in wide variety of different situations.

Preferably, in the present invention, the alarm emits a sound, for example a buzz, ring, tone, siren or recorded or synthesized message. The alarm may aim to wake the wearer by inducing vibrations in a surface of the device in contact with the skin, or in any other suitable way likely to wake a sleeping or sleepy person.

No existing sleep detection system reliably determines if the subject has been woken by the alarm.

There is a danger therefore that the subject sleeps through the alarm, or sleeps long enough to be in or cause danger and/or be in neglect of his duties.

The system according to the present invention may therefore comprise a second, e.g. remote alarm, that is preferably activated in the event that the first alarm is not switched off by operation of the reset means within an allotted time.

Thus, in further preferred embodiments of the present invention the system comprises a second alarm and a second signal generator that provides an activating signal for the second alarm if the first alarm is not after its activation reset within a pre-determined time. The pre-determined or allotted time may be variable. The activating signal for the second alarm may be optical or a radio signal, for example.

When such embodiments are employed, the first alarm is activated upon detection of a sleep state in the subject. Should the subject not reset the alarm within a pre-determined time, suggesting that the subject has not been woken by the alarm, the second alarm will be activated. This alarm may be designed to be a further attempt to wake the subject, e.g. by emitting a louder or more piercing sound, or, more preferably, may be remote from the wearer and designed to alert someone else, e.g. a manager, supervisor or controller, to the onset of the sleep in the wearer. This may prompt emergency action, for example machinery operated by the subject may be

turned off, or other pre-arranged procedure as appropriate.

Embodiments of the present invention will now be described in detail by way of example and not limitation,
5 and with reference to the following figures:

Figure 1 is a block diagram of one embodiment of the device.

Figure 2 is a second block diagram of another
10 embodiment of the invention, including a remote alarm and a means of activating said alarm.

All documents mentioned are incorporated herein by reference.

The embodiment of the present invention illustrated
15 in Figure 1 comprises a transducer 1, memory 2, processor 3, alarm 4 and alarm reset 5. Onset of sleep is determined as follows: The transducer 1 is part of a device to be worn on the wrist and detects wrist motion, information about which is then stored in memory 2. The
20 processor 3 processes the stored data in real time and generates a signal that activates the alarm 4 if a sleep state is detected. The device comprising the sleep detector comprises a manual reset button 5, operation of which resets the alarm 4.

The action of resetting the alarm manually, and so having to make some physical motion to stop the alarm, is more effective than just the alarm alone in waking an individual wearing the device.

5 The embodiment of the present invention illustrated in Figure 2 is a system comprising a second, remote alarm. Components 1-5 are as in the embodiment illustrated in Figure 1 and described above, but the wrist-worn device further comprises a delay circuit 6 and an emitter 7.

10 Determination of the wake/sleep state of a wearer is as described above with reference to Figure 1. A signal from the processor 3 is passed to the alarm 4 as before to activate the alarm 4 upon detection of a sleep state in the subject.

15 In this embodiment, however, the signal from the processor 3 is also sent to an emitter 7 which in turn generates a signal that activates the remote alarm 9 following receipt of the signal by receiver 8. Between the emitter 7 and processor 3 is a delay circuit 6 that
20 delays the signal from the processor 3 from reaching the emitter 7 for a pre-determined length of time, which may be varied according to operating preferences. As
previously, the alarm may be reset manually by operation of the reset 5. Resetting the alarm 4 also prevents the
25 signal from the processor 3 from activating the emitter 7. Provided the alarm 4 is reset before the signal activates the emitter 7, i.e. within the pre-determined time of

delay by the delay circuit 6, the second alarm 9 is not activated.

If on the other hand the first alarm 4 is not reset within the pre-determined time, emitter 7 is activated and
5 generates a radio signal. Receipt of the signal by the remote receiver 8 leads to activation of the second alarm 9. This may alert a supervisor or manager to the onset of sleep in the individual wearing the sleep detector, who may for example be operating dangerous machinery. The
10 supervisor or manager may then take appropriate action.

CLAIMS

1. A system for waking an individual upon onset of sleep, the system comprising a wearable device and an alarm, the wearable device comprising a sleep detector for
5 determining the sleep/wake state of an individual when wearing the device, a signal generator that provides an activating signal for the alarm upon detection of a sleep state by the detector, and manually operable alarm reset means.
- 10 2. A system according to claim 1 wherein the wearable device comprises the alarm.
3. A system according to claim 1 or claim 2 wherein the sleep detector comprises a motion sensor.
4. A system according to claim 3 wherein the motion
15 sensor comprises an accelerometer.
5. A system according to any of the preceding claims wherein the sleep detector comprises a blood pressure measuring device.
6. A system according to any of the preceding claims
20 wherein the sleep detector comprises a pulse rate measuring device.

7. A system according to any of the preceding claims wherein the alarm emits a sound on activation.
8. A system according to any of the preceding claims wherein the wearable device is for the wrist.
- 5 9. A system according to any of the preceding claims comprising a second alarm and a second signal generator that provides an activating signal for the second alarm if the first alarm is not after its activation reset within a pre-determined time.
- 10 10. A system according to claim 9 wherein the activating signal for the second alarm is optical.
11. A system according to claim 10 wherein the activating signal for the second alarm is a radio signal.
12. A system substantially as herein described with
15 reference to Figure 1.
13. A system substantially as herein described with reference to Figure 2.



Application No: GB 9607969.4
Claims searched: 1-13

Examiner: David Summerhayes
Date of search: 17 June 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:
UK Cl (Ed.O): G4N (NCAT, NCM, NPPXAX, NHST, NHVSB)
Int Cl (Ed.6): G08B 21/00
Other: ONLINE: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X,Y	GB2150725A (AISIN SEIKI)	X:1,6,7,8 Y:9-11
Y	GB1416425 (EMI)	9-11
X,Y	US4728939 (OTANI)	X:1,2,7 Y:9-11
X,Y	US4361834 (KING)	X:1,2,7,8 Y:9-11
X,Y	US4272764 (HERR)	X:1-3,7 Y:9-11
X,Y	US4059830 (THREADGILL)	X:1,2,7,8 Y:9-11

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.